

## **Evolutionary Design of a Single-Wire Circularly-polarized X-Band Antenna for NASA's Space Technology 5 Mission**

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### **Introduction**

A four-arm symmetric evolved antenna was presented previously to satisfy NASA's Space Technology 5 mission [1,2]. However, the mission's launch vehicle was changed, putting it into a much lower earth orbit, changing the specifications for the communications antenna. Within one month of this change, two new antennas were evolved and prototyped. Both were tested, and both had acceptable performance with respect to the new specifications. This rapid response shows that this design process is able to accommodate new requirements quickly.

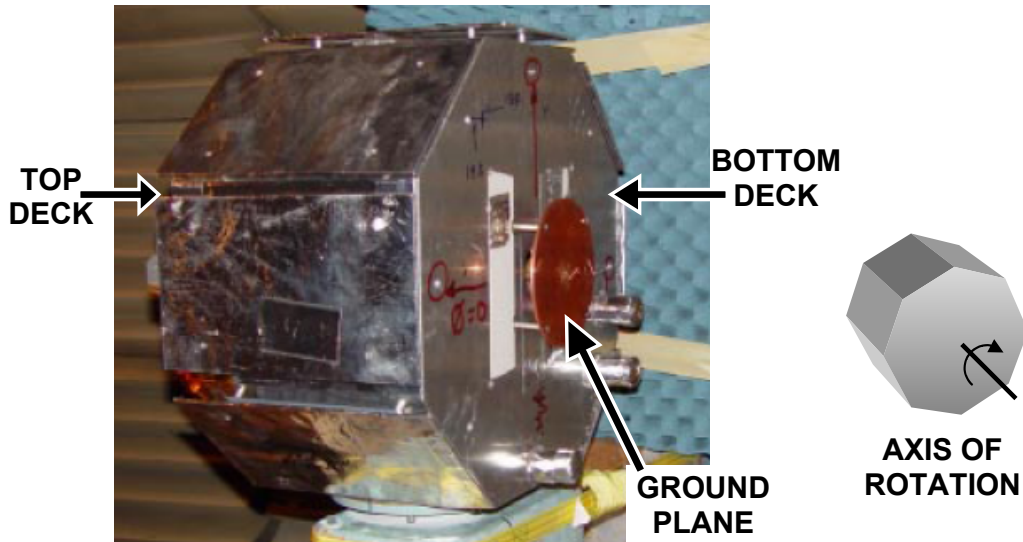
### **Requirements**

The key ST5 mission antenna requirements originally were as follows:

Transmit Frequency: 8470 MHz; Receive Frequency: 7209.125 MHz; 50 ohm impedance, VSWR:  $< 1:2 : 1$  at Transmit Freq and  $< 1:5 : 1$  at Receive Freq; Gain Pattern: 0 dBic, 40 - 80 deg. from zenith and 0 - 360; Diameter  $< 15:24$  cm; Height:  $< 15:24$  cm; Mass:  $< 165$  g. These specifications were essentially the same for the new orbit, except that the pattern requirement changed to include the following: -5 dBic, 0 - 40 deg. from zenith.

Because of symmetry, the previous 4-arm design has a null at zenith that is built into the design. The new designs that were optimized only have one arm to allow for coverage over the upper hemisphere.

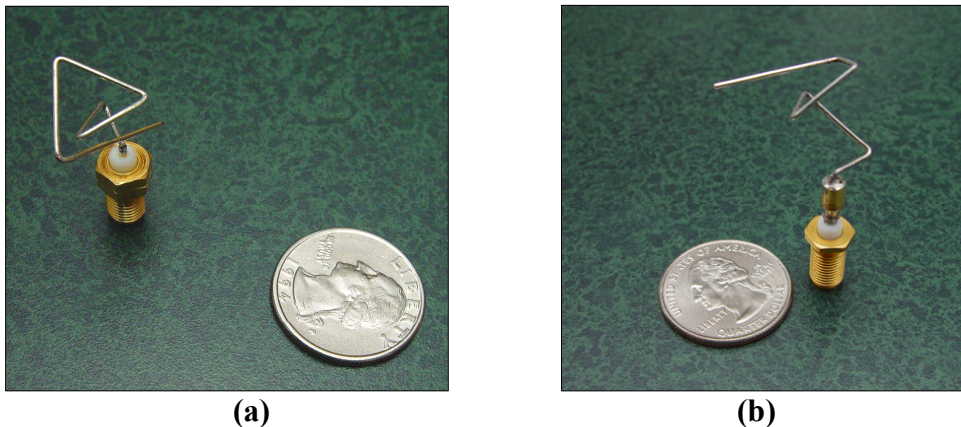
In addition, the new requirements also specify that two antennas will be combined to form a two-element passive array. One antenna will be placed on the top of the satellite, and the other on the bottom, to provide better coverage. Each antenna is placed on a ground plane approximately 2" above the deck of the satellite. It is understood that there will be nulling around the equator of the satellite as a result of this simple array configuration, but this is acceptable. This arrangement is shown in Figure 1.



**Figure 1. Photograph of ST5 mock-up with antennas mounted (only antenna on top deck is visible)**

Because the satellite is spinning at about 40 RPM, it is important that the antennas have a uniform gain pattern in azimuth. This is difficult to meet with a single-arm antenna, because it is inherently asymmetric. However, resulting designs have been able to meet this specification.

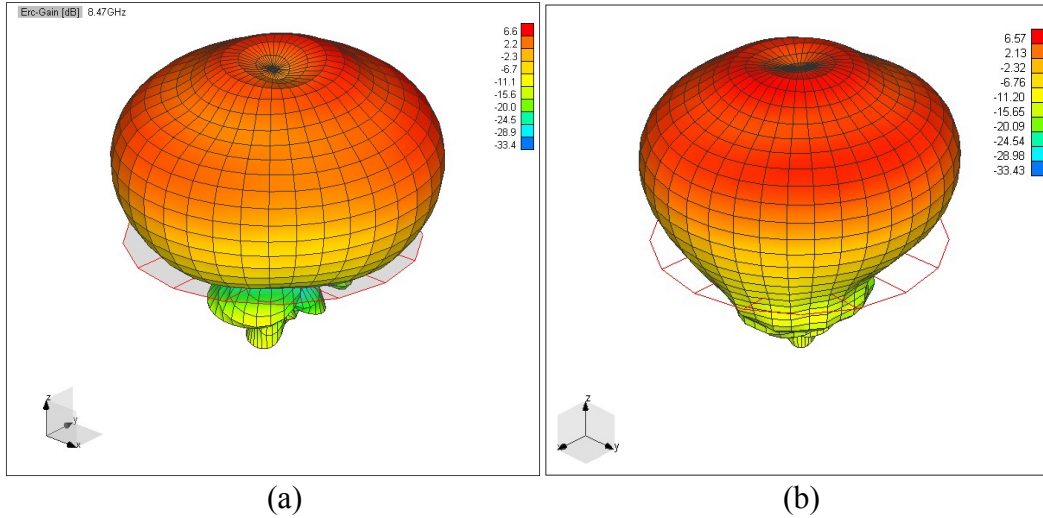
These new designs were optimized through the same processes used in [2], adding in the new pattern requirement and optimizing only one arm instead of a symmetric 4-arm design. The resulting designs are pictured in Figure 2.



**Figure 2. Evolved antenna designs, created through a vector of parameters (a), named EA-Short and a constructive process (b), named EA-Long.**

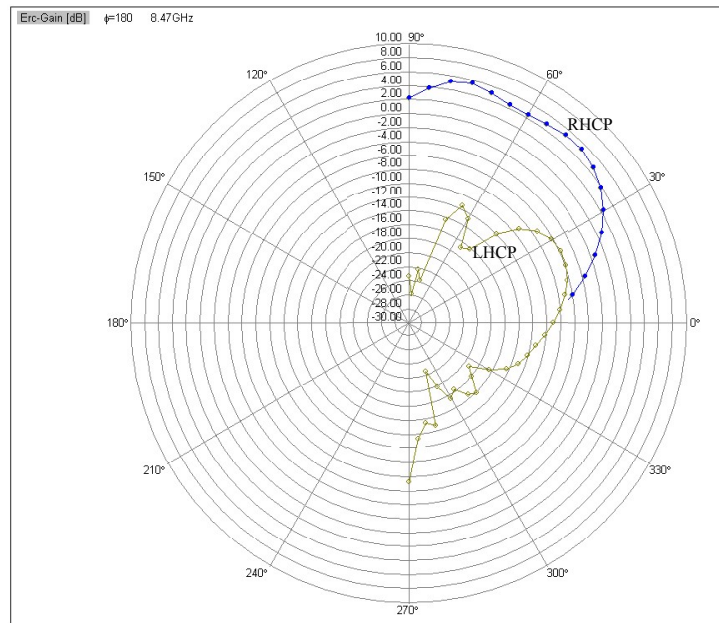
### Simulated Results

The designs both have excellent simulated RHCP patterns, as shown in Figure 3 for the transmit frequency.



**Figure 3. Simulated 3D patterns for EA-Short and EA-Long on 6" ground plane at 8470 MHz for RHCP polarization. Simulation performed by WIPL-D [3]. Patterns are similar for 7209 MHz.**

The antennas also have good circular polarization purity across a wide range of angles, as shown in Figure 5 for EA-Short. To the best of our knowledge, this quality has never been seen before in this form of antenna.

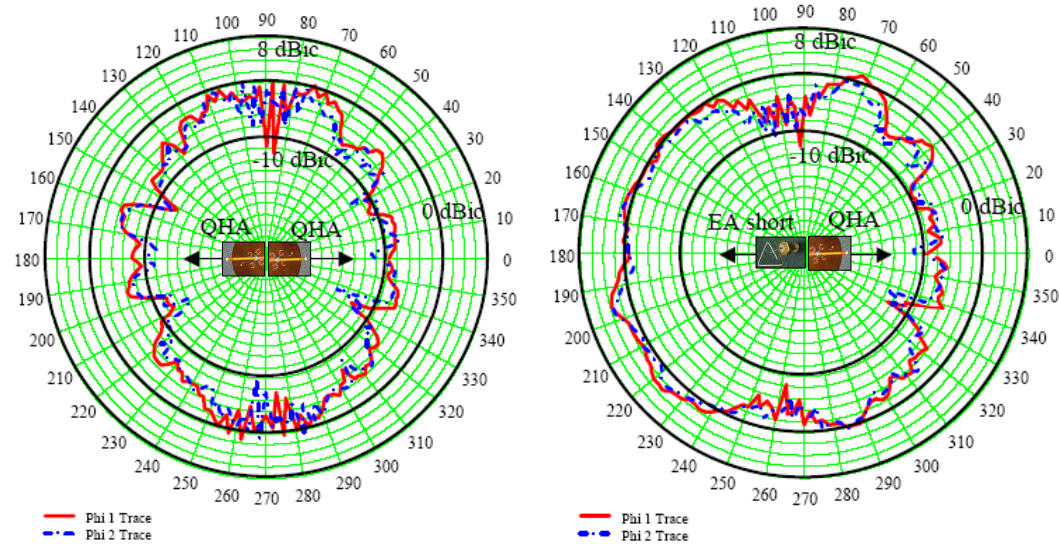


**Figure 4. RHCP vs LHCP performance of EA-Short. Plot has 2 dB/division.**

### Measured Results

The antennas were measured on the ST5 mockup, and the results are shown in Figure 6. The evolved antenna was arrayed with a Quadrafilary Helix Antenna (QHA) developed by New Mexico State University's Physical Science Laboratory that was the original antenna for this mission. The figure shows plots of two QHA antennas together, and a

QHA and an EA-Short antenna. Results are similar for EA-Long. The evolved antennas have much greater gain compared to the QHAs across the angles of interest.



**Figure 6. Measured patterns on ST-5 mockup of QHA antenna and EA-short plus QHA antenna. Phi 1 = 0 deg., Phi 2 = 90 deg.**

## Conclusion

When the mission specifications for ST5 changed, new antennas designs were created and built within 4 weeks, and they meet these new requirements. This shows that the evolved antenna design process lends itself to rapid response to changing requirements.

## Acknowledgments

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## References

- [1] Space Technology 5 Mission, Website: <http://nmp.jpl.nasa.gov/st5/>
- [2] J. D. Lohn, D. S. Linden, G. D. Hornby, W. F. Kraus, A. Rodriguez, S. Seufert, "Evolutionary Design of an X-Band Antenna for NASA's Space Technology 5 Mission," Proc. 2004 IEEE Antenna and Propagation Society International Symposium and USNC/URSI National Radio Science Meeting, Vol. 3, pp. 2313-2316, 2004.